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STERILITY OF OATS.[1]

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INTRODUCTION.

At the time when oats are maturing in the field, panicles having a part of the spikelets undeveloped or sterile are often sufficiently abundant to attract attention and to cause some concern because of the resulting reduction in yield. This sterility was first observed by the writer in connection with the halo blight of oats. In fields showing considerable halo blight there are usually some plants with the flag leaf and sheath badly spotted and yellowed. As the panicles emerge from these yellowed sheaths, often as many as half of the spikelets will be found to be sterile. This sterility usually occurs at the base of the panicle, but occasionally part of the upper spikelets are undeveloped. The fact that panicles emerging from yellowed sheaths usually show more sterility than panicles from unspotted sheaths might lead to the conclusion that the sterility is due to the bacterial disease. Thomas F. Manns, in his bulletin on the bacterial blight of oats (1909),[2] describes and figures (pl. 14, p. 161) this condition and states that "blast" (sterility) of oats is more or less directly proportional to the extent of blade blight. He says that in some cases the blast may be due directly to the killing of parts of the panicles by contact with blight lesions, but as a rule it is caused by the reduced vitality of the plant occasioned by the blade blight several weeks before the panicle emerges.

[1] These experiments were begun at the suggestion of Prof. L. R. Jones, of Madison, Wis.

[2] Manns, Thomas F. The blade blight of oats—a bacterial disease. Ohio Agr. Exp. Sta. Bul. 210, p. 161, pl. 14. 1909.

TABLE I.—*Relation between halo blight and sterility in 11 varieties of oats, as shown by inoculation experiments in 1918.*

[The extreme and average percentages of sterility are shown in boldface figures. Abbreviations (in reading columns): Minn.= Minnesota; Orga.= inoculum of halo-blight organism; Ped.= pedigree; Wis.= Wisconsin.]

Variety and bundle conditions.	Sprayed with—	Normal and sterile spikelets counted.																																	
		Panicle 1.				Panicle 2.				Panicle 3.				Panicle 4.				Panicle 5.				Panicle 6.				Panicle 7.				Panicle 8.				Panicle 9.				Panicle 10.				Average.			
		Total.	Normal.	Sterile. Number.	Sterile. Per cent.	Total.	Normal.	Sterile. Number.	Sterile. Per cent.	Total.	Normal.	Sterile. Number.	Sterile. Per cent.	Total.	Normal.	Sterile. Number.	Sterile. Per cent.	Total.	Normal.	Sterile. Number.	Sterile. Per cent.	Total.	Normal.	Sterile. Number.	Sterile. Per cent.	Total.	Normal.	Sterile. Number.	Sterile. Per cent.	Total.	Normal.	Sterile. Number.	Sterile. Per cent.	Total.	Normal.	Sterile. Number.	Sterile. Per cent.	Total.	Normal.	Sterile. Number.	Sterile. Per cent.	Total.	Normal.	Sterile. Number.	Sterile. Per cent.
Wis. Ped. 1 (Wisconsin Wonder):																																			
Bundle 1, untreated		57	44	13	22	102	86	16	15	76	71	5	**6**	37	29	8	21	39	33	6	15	43	35	8	18	58	41	17	**29**	36	32	4	11	33	27	6	18					53	44	9	**16**
Bundle 2, uninjured	Water	33	25	8	24	42	22	20	**47**	28	18	10	35	39	27	12	30	36	23	13	36	65	48	17	26	32	22	10	31	25	23	2	**8**	25	14	11	44	18	15	3	16	34	27	10	**29**
Bundle 3, uninjured	Orga	25	19	6	24	54	24	30	**55**	57	43	14	24	71	57	14	**19**	23	17	6	26	50	32	18	36	46	28	18	39	32	21	11	34	37	21	16	43	40	26	14	35	43	28	14	**32**
Bundle 4, in sheaths	Water	66	58	8	**12**	56	40	16	28	58	42	16	27	53	46	7	13	61	43	18	**29**	45	38	7	15	86	70	16	18													60	48	12	**20**
Bundle 5, in sheaths	Orga	47	33	14	29	55	34	21	38	30	25	5	**16**	56	38	18	32	34	23	11	32	48	38	10	20	46	32	14	30	58	47	11	18	53	28	25	**47**					47	33	14	**29**
Wis. Ped. 3 (Tobolsk):																																			
Bundle 1, untreated		43	40	3	6	33	30	3	9	33	30	3	9	49	38	11	**22**	34	29	5	14	45	41	4	8	44	39	5	11	40	38	2	**5**	40	38	2	5	41	35	6	14	40	35	4	**10**
Bundle 2, uninjured	Water	19	17	2	10	26	23	1	3	20	17	3	15	20	17	3	15	21	19	2	9	15	14	1	6	15	15	0	0	22	18	4	18	22	22	0	**0**	35	24	11	**31**	21	18	2	**9**
Bundle 3, uninjured	Orga	19	17	2	10	28	25	3	10	21	20	1	4	35	35	0	0	27	23	4	14	23	23	0	**0**	33	31	2	6	29	27	2	6	33	27	6	**18**	30	28	2	6	27	25	2	**7**
Bundle 4, uninjured	...do	36	33	3	8	26	22	4	15	35	30	5	14	49	46	3	6	43	40	3	**6**	30	23	7	23	27	24	3	11	23	19	4	17	34	27	7	20	29	20	9	**31**	33	28	4	**12**
Wis. No. 4 (Swedish Select):																																			
Bundle 1, untreated		26	23	3	11	19	17	2	10	28	27	1	**3**	32	29	3	9	30	25	5	**16**	16	15	1	6	20	19	1	5	32	28	4	12	47	45	2	4	35	30	5	14	28	25	2	**7**
Bundle 2	Water	29	27	2	6	41	38	3	7	31	27	4	12	40	33	7	17	50	47	3	6	34	29	5	14	32	32	0	**0**	36	33	3	8	48	38	10	**20**	32	28	4	12	37	33	4	**10**
Bundle 3	Orga	45	41	5	11	45	36	9	20	48	44	4	**8**	49	37	12	24	41	28	13	**31**	38	30	8	21	31	26	5	16	56	44	12	21	33	24	9	27	28	23	5	17	41	33	8	**19**
Wis. Ped. 5 (Swedish Select):																																			
Bundle 1, untreated		40	35	5	12	15	12	3	**20**	18	16	2	11	28	28	0	**0**	23	23	0	**0**	30	25	5	16	23	21	2	8	18	17	1	5	20	20	0	**0**	29	24	5	17	24	22	2	**8**
Bundle 2	Water	32	24	8	25	46	36	10	21	34	22	12	35	38	24	14	35	56	43	13	23	50	58	2	3	34	19	15	44	56	38	18	32	49	34	15	30	33	18	15	**45**	43	31	12	**27**
Bundle 3	...do	36	28	8	22	37	24	13	35	39	22	17	43	40	34	6	**15**	35	25	10	28	53	38	15	28	54	35	19	35	37	20	17	**45**	42	32	10	23	38	28	10	26	41	28	12	**29**
Bundle 4, uninjured	Orga	46	31	15	**22**	47	42	5	**10**	51	44	7	13	47	38	9	19	43	35	8	18	55	47	8	14	50	40	10	20	46	38	8	17	56	46	10	17	56	50	6	10	49	41	8	**16**
Bundle 5, injured (bloom off)	...do	50	30	20	40	58	34	24	**41**	42	30	12	28	60	42	18	30	48	36	12	25	49	44	5	**10**	42	30	12	28	45	29	16	35	36	26	10	22	57	38	19	33	48	33	14	**29**
Wis. Ped. 7 (Kherson):																																			
Bundle 1, untreated		20	19	1	**5**	22	22	0	**0**	47	47	0	0	47	47	0	0	50	50	0	0	33	33	0	0	26	26	0	0	46	43	3	6	45	45	0	0	42	41	1	2	37	37	0.5	**1**
Bundle 2	Water	30	26	4	**13**	21	20	1	4	32	32	0	**0**	29	29	0	0	28	28	0	0	47	45	2	4	36	36	0	0													31	30	1	**3**
Bundle 3	...do	21	19	2	**9**	37	35	2	5	43	42	1	2	30	30	0	**0**	35	33	2	5	22	22	0	0	42	41	1	2	38	37	1	2	25	24	1	4	24	24	0	0	31	30	1	**3**
Bundle 4, uninjured	Orga	37	37	0	**0**	46	41	5	**10**	40	37	3	7	52	49	3	5	48	46	2	4	57	55	2	3	44	40	4	9	44	44	0	0	39	38	1	2	39	36	3	7	44	42	2	**4**
Bundle 5, injured	...do	53	46	7	**13**	30	29	1	3	44	42	2	4	53	53	0	**0**	33	25	8	**24**	55	47	8	**14**	35	32	3	8	55	55	0	0	47	44	3	6	44	41	3	6	44	41	3	**6**

| | | |

It is quite evident, however, that considerable sterility occurs on oat panicles which have not come in contact with diseased leaves or sheaths, and even in fields where there has been little or no bacterial blight; also there is evidence that in years of severe bacterial blight early in the season the yield per acre has not been reduced, but sometimes has been greater than when there was less blight.

In order to learn more about the relationship of the halo blight to the sterility of oats the observations and experiments described in the following pages were made.

EXPERIMENTS OF 1918.

During the season of 1918, 11 varieties of oats were used for inoculation experiments. In each variety bundles containing about a dozen plants were sprayed with water suspensions of the halo-blight organism and covered with glassine bags for two or three days. One bundle was sprayed without being injured in any way and another after the plants had been drawn between the fingers to rub off the bloom. The plants of a third bundle of each variety were injured by needle pricks or were cut with a scalpel before spraying. Check bundles of each variety, injured and uninjured, were sprayed with sterile water and also covered with bags. In some cases water suspensions of the organism were sprayed into unopened sheaths and sterile water into similar plants as checks. (Pls. I to IV.)

In most of the varieties the sheaths were about ready to open or were already partly open. In Wisconsin Pedigree 7 the heads were entirely out of the sheaths and were inoculated to learn whether or not the spikelets themselves were susceptible to infection with the halo-blight organism and what the effect of infection would be. In the oat panicle the uppermost spikelets develop first and at the time when the sheath is about ready to open are usually fully grown, while those at the base are still only partly developed. The difference in the stage of development of the spikelets on the panicle influences, of course, the results of the experiments where inoculations are made upon panicles about to emerge from the sheath. The almost fully developed spikelets at the top are less influenced by the inoculum than the partly developed ones at the base.

When these inoculated and check plants were mature and were collected for recording the results, a bundle of untreated plants of each variety was also collected in order to compare the proportion of sterility with that of treated plants. The results of this set of inoculations, together with the amount of sterility found on untreated plants, are shown in Table I, and a brief summary of the same is presented in Table II.

WISCONSIN NO. 22 OATS, IMPROVED LIGOWO (MINNESOTA NO. 6), UNTREATED.

Collected in July, 1918, at Madison, Wis. Photographed in January, 1921. Three-fourths natural size.

WISCONSIN NO. 22 OATS, SPRAYED WITH STERILE WATER ON JUNE 29, 1918.

Collected in July, 1918. Photographed in January, 1921. Three-fourths natural size.

WISCONSIN NO. 22 OATS, SPRAYED WITH WATER SUSPENSION OF "STOCK" HALO ORGANISM.

Not injured before spraying on June 29, 1918. Collected in July, 1918. Photographed in January, 1921. Three-fourths natural size.

WISCONSIN NO. 22 OATS, SPRAYED ON JUNE 29, 1918, WITH WATER SUSPENSION OF "STOCK" HALO ORGANISM AFTER INJURY BY NEEDLE PRICKS.

Collected in July, 1918. Photographed in January, 1921. Three-fourths natural size.

TABLE II.—*Average percentages of sterility in 11 varieties of oats, as shown by inoculation experiments in 1918.*

Variety.	Untreated, uninjured.	Sprayed with water.		Sprayed with organism.	
		Uninjured.	Injured.	Uninjured.	Injured.
Wisconsin Pedigree 1	16	29		32	
Wisconsin Pedigree 3	10	9		12 7	
Wisconsin No 4	7	10		19	
Wisconsin Pedigree 5	8	27 29		16	29
Wisconsin Pedigree 7	1	3 3		4	6
Wisconsin Pedigree 13	15	35	47	25	46
Wisconsin Pedigree 14	7	23	5 15		21
Wisconsin Pedigree 15	0.4		6 7		16 12
Wisconsin No. 22	14	42 44		40	
Wisconsin No. 25	16 14	40		50	63
Wisconsin No. 49	14	41 48			

On normal untreated plants of the 11 varieties tested the amount of sterility varied from a fraction of 1 per cent to as much as 16 per cent. Sprayed with water suspensions of bacteria and with sterile water and treated as previously described, the proportion increased from 2 to 47 per cent. In some cases there was more sterility on plants sprayed with bacterial suspensions than on plants of the same variety sprayed with sterile water. In other varieties the reverse was true. On the whole, the amounts of sterility produced by either method seem to be about equal. If this is so, the bacteria are not the cause of the sterility in the varieties included in these experiments.

Wisconsin Pedigree 7 oats were sprayed when the panicles were entirely out and the spikelets practically full size. Although every spikelet was yellowed with halo lesions, the spikelets continued to fill out, as in untreated panicles.

In a plat of Wisconsin Pedigree 14 oats which was untreated a few panicles appeared which showed halo lesions on from a few to all of the spikelets in a panicle, but in spite of these lesions the spikelets were apparently as well developed as those unspotted.

EXPERIMENTS OF 1920.

During the season of 1920 panicles of oats were collected at random in oat fields and counts made of sterility; also another set of experiments was carried on to learn more of the possible relation of bacteria to sterility in oats. Bacterial suspensions and sterile water were sprayed into the unopened sheaths of plants about two-thirds grown. These were covered with glassine bags for three days, as in previous experiments. The results of these tests are shown in Tables III and IV.

TABLE III.—*Counts of sterility observed in oat panicles collected at random in a field of Wisconsin Pedigree 1 (Wisconsin Wonder), at Madison, Wis., July 21, 1920.*

[The extreme and average percentages of sterility are shown in boldface figures.]

Panicle.	Normal and sterile spikelets counted.											
	Bundle 1.				Bundle 2.				Bundle 3.			
	Total.	Normal.	Sterile.		Total.	Normal.	Sterile.		Total.	Normal.	Sterile.	
			Number.	Per cent.			Number.	Per cent.			Number.	Per cent.
No. 1	45	42	3	6	40	34	6	15	67	52	15	22
No. 2	53	45	8	15	50	45	5	10	51	41	10	19
No. 3	38	27	11	**28**	43	38	5	11	82	58	24	29
No. 4	44	42	2	4	32	28	4	12	61	45	16	27
No. 5	40	32	8	20	65	41	24	**37**	85	60	25	29
No. 6	40	39	1	**2**	37	33	4	10	72	54	18	25
No. 7	42	38	4	9	31	29	2	**6**	75	49	26	34
No. 8	41	37	4	9	38	34	4	10	93	66	27	29
No. 9	34	25	9	26	55	41	14	25	62	52	10	**16**
No. 10	38	32	6	15	41	35	6	14	62	46	16	25
No. 11	42	39	3	7	54	37	17	31	77	62	15	19
No. 12	60	48	12	20	54	37	17	31	73	40	33	**45**
No. 13					50	35	15	30	81	52	29	35
No. 14									69	45	24	34
No. 15									90	67	23	25
No. 16									76	53	23	30
No. 17									78	55	23	29
No. 18									65	50	15	23
No. 19									51	35	16	31
No. 20									78	59	19	24
No. 21									72	54	18	25
No. 22									45	34	11	24
No. 23									48	37	11	23
No. 24									43	29	14	33
No. 25									49	40	9	18
No. 26									47	35	12	25
No. 27									53	40	13	24
No. 28									72	56	16	25
Average	43	37	5	**13**	45	35	9	**18**	67	48	18	**26**

The panicles recorded in Table III were collected on July 21 without regard to sterility from an acre plat on the agricultural grounds of the University of Wisconsin. It was noticeable that every panicle showed some sterility, the amount varying from 1 spikelet per panicle in bundle 1 to 33 spikelets per panicle in bundle 3. This field from which the panicles were taken was practically free from halo blight. There were no lesions on the upper leaves, flag leaves, or panicles, and only an occasional lesion on a lower leaf could be found. In the case of this variety there seems to have been no connection whatever between the halo blight and the sterility recorded above, yet in bundles 2 and 3 the average sterility was more than a third of the whole number of spikelets.

In the 1920 experiments (Table IV), as in 1918, water and bacterial suspensions sprayed into oat sheaths produced more sterility than occurred naturally. The average of 21 per cent of sterility on untreated plants is high, but this increased to 40 and 52 per cent when water was sprayed into the sheaths and to 44 and 63 per cent with bacterial suspensions. In this experiment the bacterial sus-

pension retarded growth more than the sterile water. In a number of cases the panicles did not push out of the sheaths, remaining undeveloped inside, and were so moldy that it was practically impossible to make counts. How much the mold had to do in retarding development could not be determined. Counts from these panicles are given where possible.

TABLE IV.—*Relation of halo blight and stripe organisms to sterility in oats, as shown by inoculation experiments with Wisconsin Pedigree 5 (Swedish Select) at Madison, Wis., June 25, 1920.*

[The extreme and average percentages of sterility are shown in boldface figures.]

Panicle.	Normal and sterile spikelets in treated and untreated panicles. Inoculum in sheaths.																					
	Untreated, bundle 1.				Sterile water.								Halo-blight organism.								Stripe organism, bundle 6.			
					Bundle 2.				Bundle 3.				Bundle 4.				Bundle 5.							
			Sterile.				Sterile.				Sterile.				Sterile.				Sterile.				Sterile.	
	Total.	Normal.	Number.	Per cent.	Total.	Normal.	Number.	Per cent.	Total.	Normal.	Number.	Per cent.	Total.	Normal.	Number.	Per cent.	Total.	Normal.	Number.	Per cent.	Total.	Normal.	Number.	Per cent.
No. 1	52	38	14	26	22	12	10	45	31	18	13	41	17	10	7	41	...	10	...	...	...	5	...	...
No. 2	64	51	13	20	30	18	12	40	34	13	21	61	16	10	6	37	27	18	9	31	...	0	...	**100**
No. 3	58	46	12	20	37	23	14	37	20	9	11	55	...	0	...	**100**	12	11	1	**8**	29	12	17	58
No. 4	47	26	21	**44**	25	13	12	48	20	10	10	50	...	...	...	50	21	14	7	33	...	0	...	100
No. 5	53	44	9	16	33	18	15	45	20	8	12	60	20	9	11	55	28	13	15	53	43	31	12	**27**
No. 6	50	38	12	21	21	15	6	27	11	3	8	**72**	28	16	12	42	19	11	8	42	46	30	16	34
No. 7	36	24	12	33	39	25	14	35	30	16	14	46	...	0	...	100	...	0	...	**100**	...	5	...	...
No. 8	25	21	4	16	25	11	14	56	22	13	9	40	...	0	...	100	21	13	8	38	...	...	...	...
No. 9	43	41	2	**4**	23	12	11	47	28	11	17	60	22	10	12	54	21	10	11	52	...	...	...	...
No. 10	44	32	12	27	24	13	11	45	19	7	12	63	19	9	10	52	32	17	15	46	...	...	...	...
No. 11	41	28	13	21	21	12	9	42	27	9	18	66	23	11	12	52	...	...	...	...	...	...	...	...
No. 12	58	51	7	12	23	16	7	30	21	8	13	61	...	0	...	100	...	...	...	...	...	...	...	...
No. 13	...	...	...	...	37	26	11	29	23	9	14	60	...	4	...	...	...	...	...	...	...	...	...	...
No. 14	...	...	...	...	28	19	9	32	28	16	12	42	...	8	...	...	...	...	...	...	...	...	...	...
No. 15	...	...	...	...	26	10	16	**61**	25	9	16	64	...	8	...	...	...	...	...	...	...	...	...	...
No. 16	...	...	...	...	19	15	5	**21**	15	7	8	53	...	...	...	...	...	...	...	...	...	...	...	...
No. 17	...	...	...	...	30	13	17	56	24	14	10	41	...	...	...	...	...	...	...	...	...	...	...	...
No. 18	...	...	...	...	...	...	...	...	29	16	13	44	...	...	...	...	...	...	...	...	...	...	...	...
No. 19	...	...	...	...	...	...	...	...	20	10	10	50	...	...	...	...	...	...	...	...	...	...	...	...
No. 20	...	...	...	...	...	...	...	...	24	10	14	58	...	...	...	...	...	...	...	...	...	...	...	...
No. 21	...	...	...	...	...	...	...	...	33	18	15	45	...	...	...	...	...	...	...	...	...	...	...	...
No. 22	...	...	...	...	...	...	...	...	33	17	16	48	...	...	...	...	...	...	...	...	...	...	...	...
No. 23	...	...	...	...	...	...	...	...	26	13	13	50	...	...	...	...	...	...	...	...	...	...	...	...
No. 24	...	...	...	...	...	...	...	...	22	14	8	**36**	...	...	...	...	...	...	...	...	...	...	...	...
No. 25	...	...	...	...	...	...	...	...	24	12	12	50	...	...	...	...	...	...	...	...	...	...	...	...
Average	47	36	10	**21**	27	15	11	**40**	24	11	12	**52**	...	...	...	65	...	...	...	**44**	...	...	...	**63**

GENERAL SUMMARY.

Considerable sterility occurs on oat panicles without any apparen connection with halo blight and in fields where there are no bacterial lesions. The amount seems to vary with different varieties of oats, some showing more sterility than others during the same season under similar conditions.

The amount of sterility does not appear to be in proportion to susceptibility to halo blight. Wisconsin Pedigree No. 14 oats is the most susceptible to halo blight of the 11 varieties tested, but does not

show the greatest amount of sterility. By spraying plants with sterile water or water suspensions of bacteria and covering them for two or three days, the amount of sterility can be greatly increased. Although abundant halo lesions result from spraying with bacterial suspensions, the consequent sterility is only slightly, if any, greater in amount than that induced by sterile water.

It seems probable that rains falling about the time the oat sheaths are ready to open may have the same effect as the sterile water used in the experiments recorded here and that most of the sterility observed in oat fields is not the result of the halo-blight organism but of too much moisture about developing panicles.

The striking variations in percentages of sterility in different panicles of the same bundle (Table I, Wis. Ped. 14, bundles 1 to 6) and the high percentages of sterility in all the panicles of a few bundles (Table I, Wis. No. 25, bundles 4 and 5, and Table I, Wis. No. 22, bundles 3 and 4, 1918; also Table IV, bundles 2, 3, and 4, 1920) would seem to point to the condition of the oat flowers at the time of rain or spraying as a controlling factor in the amount of sterility. If, however, the variations in the amounts of sterility in different varieties should prove constant from year to year the varieties found to be susceptible could be discarded and hardier ones grown. Records for several years from parallel plats of varieties which have shown different amounts of sterility in one season might give interesting and practical results.

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